CENE 486C

Final Design Report

May 9th, 2017

Team Flaming Bunnies (2016-2017)

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1.0 ACKNOWLEDGEMENTS

We would like to acknowledge and thank Tom Runyon who is the coordinator hydrologist for the Coconino National Forest. Tom is our client but also a strong supporter for the work we are doing. In addition, we would like to thank Kit MacDonald who is the soil and watershed program manager for the Coconino and Kaibab National Forest. Kit has helped us with fieldwork and gathering samples. As well as providing feedback and support towards any of our concerns. Both professionals supported our design project and we are grateful for their contributions. Also, Mark Lamer who helped us with our AutoCAD issues, Lar Reiboldt who guided us with our geotechnical laboratory work, and Pete Page who was the contractor that provided us with quotes of the cost to implement our design alternatives.

2.0 PROJECT DESCRIPTION

2.1 BACKGROUND

The Allan Lake Wetland Restoration project aims to restore the wetlands' historical ability to retain water and support wetland vegetation. The fine particle clay layer that had acted as an impermeable water-holding layer was disturbed during a habitat improvement effort, resulting in a loss of wetland function. The purpose of this project is to improve the distribution and retention of water in the wetland area. The Forest Service has a rough idea of how they would like to approach the restoration, they have previously used a bull dozer and half a dozen workers to carry out a test restoration in a single section. Figures C1 through C3 in the Appendix show the differences that are observable at the site between the unrestored area and the test restoration section. The Forest Service then put out a bid to contractors to see how much it would cost to have the entire lake restored like their test section, however they did not include a soil analysis of the site, which made the bids range from $40,000 to $250,000. The main objective for the students is to conduct the soil analysis, and then based on the soil analysis complete a cost analysis for the restoration to find a more accurate and exact price for our client Tom Runyon.

Allen Lake is located 2.7 miles north of the intersection of Lake Mary Road and Stoneman Lake Road, along Lake Mary Road where it can be seen in Appendix A (Latitude 34º 49' 34.09" N, Longitude: 111 º 26' 27.45'' W). Currently, the lake is a series of ditches surrounding a grassy field, as shown in the Appendix B. In 1986 Arizona Game and Fish tried to improve waterfowl habitat by creating the series of ditches in the seasonal Allan Lake area. Their thinking was that this would allow the water to pool, creating a permanent lake, and would protect the waterfowl from predators. By creating the ditches with bulldozers and explosives, they disturbed the water retention layer in the soil, causing the lake to dry much quicker and thus reducing waterfowl habitat.

Our client is the United States Forest Service (USFS). Tom Runyon is our secondary client who is a coordinator hydrologist for the Coconino National Forest. Our stakeholders are the species and plants of the wetland, people who own land and utilities adjacent to the impacted areas, Arizona Game and Fish, and the general public who has unrestricted access to the site.

2.2 Site Conditions

During the fall when the site was surveyed and the soil samples were gathered, the site was relatively dry and easy to traverse (this can be seen in Figure C1 in the Appendix). This contrasts with the conditions of the site during the months January and February. The site was heavily flooded with snow on the ground, as shown in Figures C4 though C6 in the Appendices. This posed the problem of not being able to gather more soil samples until Allan Lake had melted and dried up. However, during the month of March the team was able to go to a remote location to collect more samples in order to conduct more geotechnical lab analysis. The main limitation of this project was what the site and weather conditions were like during the time of site visits.

2.3 Tasks and Sub Tasks

Below is an outline of the tasks that need to be finished in order to successfully complete the project [5].

- Task 1.0: Research
- Task 2.0: Field Work
  - 2.1: Survey & Create a Topographic Map
  - 2.2: Soil Sampling
  - 2.3: Soil Profile from Auger Boreholes
- Task 3.0: Geotechnical Lab Analysis
  - 3.1: ASTM D2974-Moisture Content
  - 3.2: ASTM D2974-Organic Content
  - 3.3 ASTM D4318-Atterberg Limits
  - 3.4 ASTM C325-Wet Sieve Analysis
  - 3.5: ASTM D5084-Hydraulic Conductivity
  - 3.6: ASTM D-698-Proctor Compaction
- Task 4.0: Develop Design
  - 4.1: Develop Compaction Specification
  - 4.2: Cut and Fill
  - 4.3: Cost Analysis
- Task 5.0: Project Management
  - 5.1: Communication
    - 5.1a: Client Meetings
    - 5.2b: Team Meetings
  - 5.2: Deliverables
    - 5.2a: Final Report
    - 5.3b: Presentation
    - 5.3: Website

3.0 Technical Section

3.10 Testing and Analysis

Prior to conducting geotechnical lab analysis, soil sampling and surveying work were both completed as part of the fieldwork for the project. While collecting samples at the project site, we used a bore auger instrument to collect a soil profile. One of the bore logs used during the acquisition of samples can be seen in Appendix E. A total of 28 soil samples were initially collected from 13 sampling sites by the team, and shown below are some of the representative profiles:

Figure 3.11: Soil profile of the undisturbed sections of Allan Lake.

Figure 3.12: Soil profile of the side cast mix near the trenches.

Figure 3.13: Soil profile of the trenches.

Based on the soil samples collected, we found that parts of the wetland were undisturbed by Arizona Game and Fish. Thus, these soil profiles represent the soil layers for the undisturbed area (before the excavation of Arizona Game and Fish) and the disturbed soils, which are the side casted mixed piles and the trenches. The first layer of soil from the undisturbed area (shown below in Figure 3.14) is the top soil, which indicates organic content and plants. The second layer is the hydric soil, which indicates the top clay layer; periodically moisturized and dark. The third layer is the oxidation layer and iron deposits, but also heavy clay (shown as “the bottom clay layer”) which is indicated by the red color (as shown in figure 3.13). The fourth layer is the sandy lean clay mixture. On the next page, a simplistic image of the layers is shown:

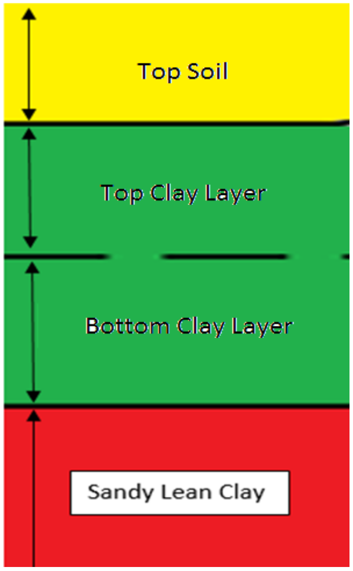


Figure 3.14: The soil profile of the undisturbed soils at Allan Lake.

The following table shows the depths of which represents each layer in the undisturbed sections of Allan Lake:

Table 3.15: Undisturbed soil profile data.

Undisturbed Soil Profile		
Layer Description	**Thickness (inch)**	**Average Depth (feet)**
Top Soil	0”-6”	0’-0.5’
Top Clay Layer	11’’-30’’	0.5’-2.5’
Bottom Clay Layer	26’’-36’’	2.5’-5’
Sandy Bottom Layer	N/A	5’ and below

The following figure gives a visual representation of the soil profile of the side cast mixture near the trenches:

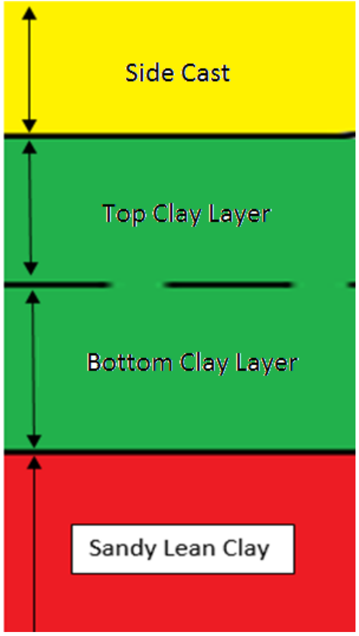


Figure 3.16: The soil profile of the side casted mixture near the trenches.

The following table shows the depths of which represents each layer in the undisturbed sections of Allan Lake:

Table 3.17: Disturbed soil profile data.

Disturbed Soil Profile		
Layer Description	**Thickness (inch)**	**Average Depth (feet)**
Side Cast	0”-18”	0’-1’
Top Clay Layer	11”-30”	1’-3’
Bottom Clay Layer	26”-26”	3’-5.5’
Sandy Bottom Layer	N/A	5.5’ and below

After collecting soil samples and capturing each soil profile, we conducted surveying work. The Team conducted multiple site visits in order to collect data points. On our first day of surveying, we established 5 control points with a total station. However, due to the size of the area a GPS survey unit was utilized, as provided by the Forest Service. Kit MacDonald, a soil scientist for the Kaibab Forest Service, assisted with the setup and calibration of the GPS survey unit. Shown on the next page is the total station used for set the control points for the surveying work:

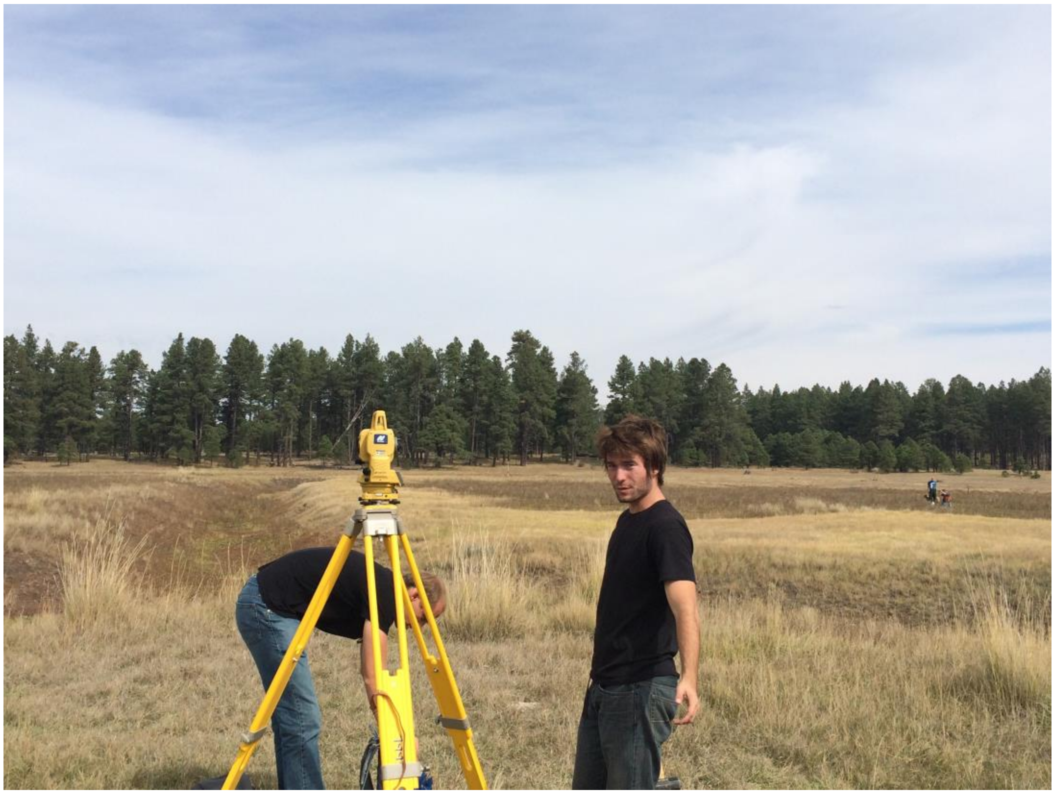


Figure 3.18: Surveying Allan Lake in the Fall of 2016.

Starting from October of 2016 and ending in December of 2016, we were able to collect 2871 points. With the help of the Forest Service and their GPS instrument, we were able to gather points for an area of 17 acres. Since the GPS instrument allowed for quick point taking, the following plan was developed: when measuring the trenches, a total of 9 points were to be taken in a line that runs perpendicular to the trench. Starting at the top edge of the trench, the next point was taken at ¼ of the way down, the next point was taken ¾ of the down the trench, and the final point on the one side of the trench was the tow, or the bottom of the trench wall. The process was repeated on the opposite side, in addition to taking a point at the thalwag. For the leveled sections of Allan Lake, a point was taken every 6 paces.

A topographical map was developed from the obtained points can be seen in the figure below along with a key as a table for this topographic map:

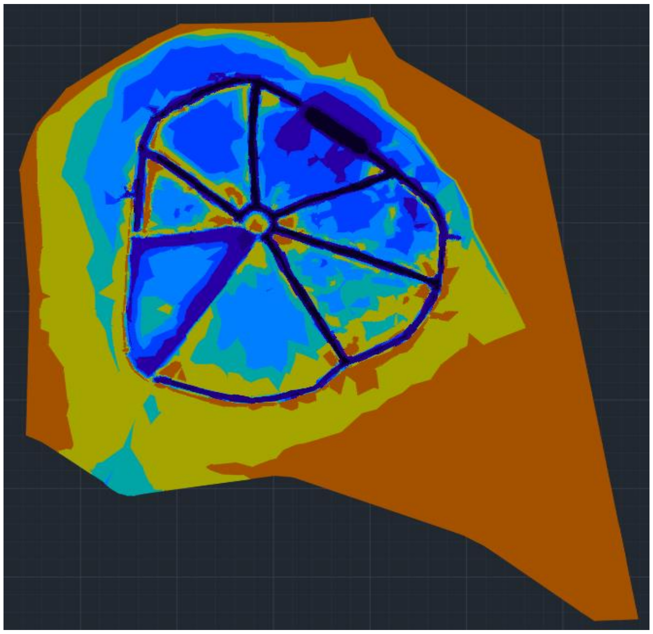


Table 3.110: Key for topographic map.

Maximum Elevation (feet)	Minimum Elevation (feet)
7473.04	7461.99
7461.99	7461.30
7461.30	7460.98
7460.98	7460.54
7460.54	7459.89
7459.89	7458.64
7458.64	7457.06
7457.06	7453.90

Figure 3.19: The topographic map of Allan Lake.

It should be noted that the existing outlet is 7461.30 feet in elevation. Also below is a developed TIN surface of Allan Lake:

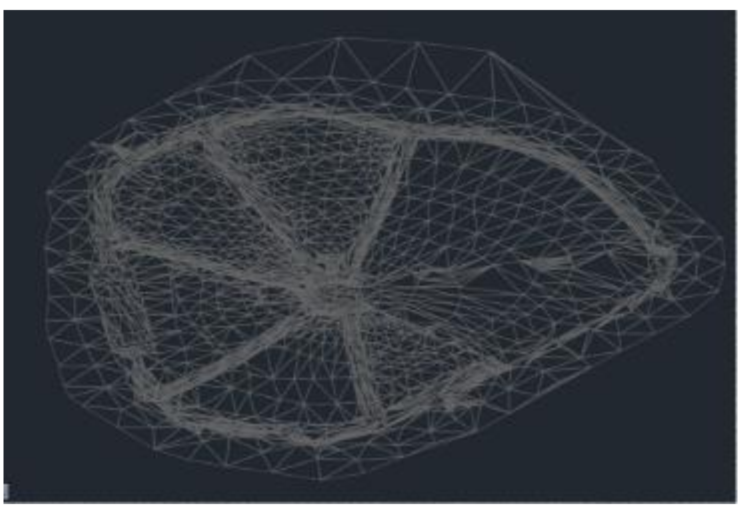


Figure 3.111: TIN surface of Allan Lake.

After conducting gathering samples and surveying, the team started on the geotechnical lab analysis. Our first geotechnical lab work was determining the organic content in the top soil (within 12 inches from the surface). In the next page is a table that shows the organic content of each soil profile as well as the average organic content and the standard deviation:

Table 3.112: Organic Results for the top soil in each sample soil profile.

Samples	Sample 1 (Undisturbed)	Sample 3 (Trench)	Sample 5 (Side Casted)	Sample 6 (Undisturbed)	Sample 9 (Side Casted)	Sample 11 (Trench)	Sample 13 (Undisturbed)
Organic (%)	8.17	6.92	9.12	8.74	8.13	7.65	9.56
Samples	Sample 16 (Trench)	Sample 18 (Side Casted)	Sample 21 (Undisturbed)	Sample 23 (Trench)	Sample 25 (Undisturbed)	Sample 27 (Side Casted)	
Organic (%)	6.63	7.79	11.73	7.24	9.41	9.05	
	Average = 8.47%		Standard Deviation = 1.36%				

Reference Appendix D to see the organic results for each of the samples per soil profile. It was noted that the average organic content in the top soil (within 12 inches of the surface) was 8.47% weight with a standard deviation of 1.36%.

Next, we conducted the Liquid Limit, Plastic Limit, Hydraulic Conductivity, Proctor Compaction, and Wet Sieve Analysis tests during the Months of February and March. The geotechnical lab analysis is summarized in the table on the next page:

Table 3.113: Soil analysis results.

Soil	Liquid Limit (%)	Plastic Limit (%)	% Fines	USCS Soil Classification	Hydraulic Conductivity (cm/s)	Organic Content	Proctor Compaction Results- Ideal Moisture Content (%)
Side Casted Soil	59.8	49	75	Lean Clay with Sand	2.3 x 10^-5	12%	59.8
Top Clay Layer	71	40.6	93	Lean Clay	>1.0 x 10^-7*	8%	71
Bottom Clay Layer	63.4	38.6	95	Lean Clay	>1.0 x 10^-7*	6%	63.4
Sandy Bottom Layer	49	21	70	Sandy Lean Clay	4.8 x 10^-2	3%	49

3.20 IDENTIFICATION OF ALTERNATIVES

After conducting the soil analysis, AutoCAD was used to help derive alternatives for remodifying the wetland. In this figure below, it shows a comparison between alternative 1 and 2, but also gives a visual representation of the current site conditions:

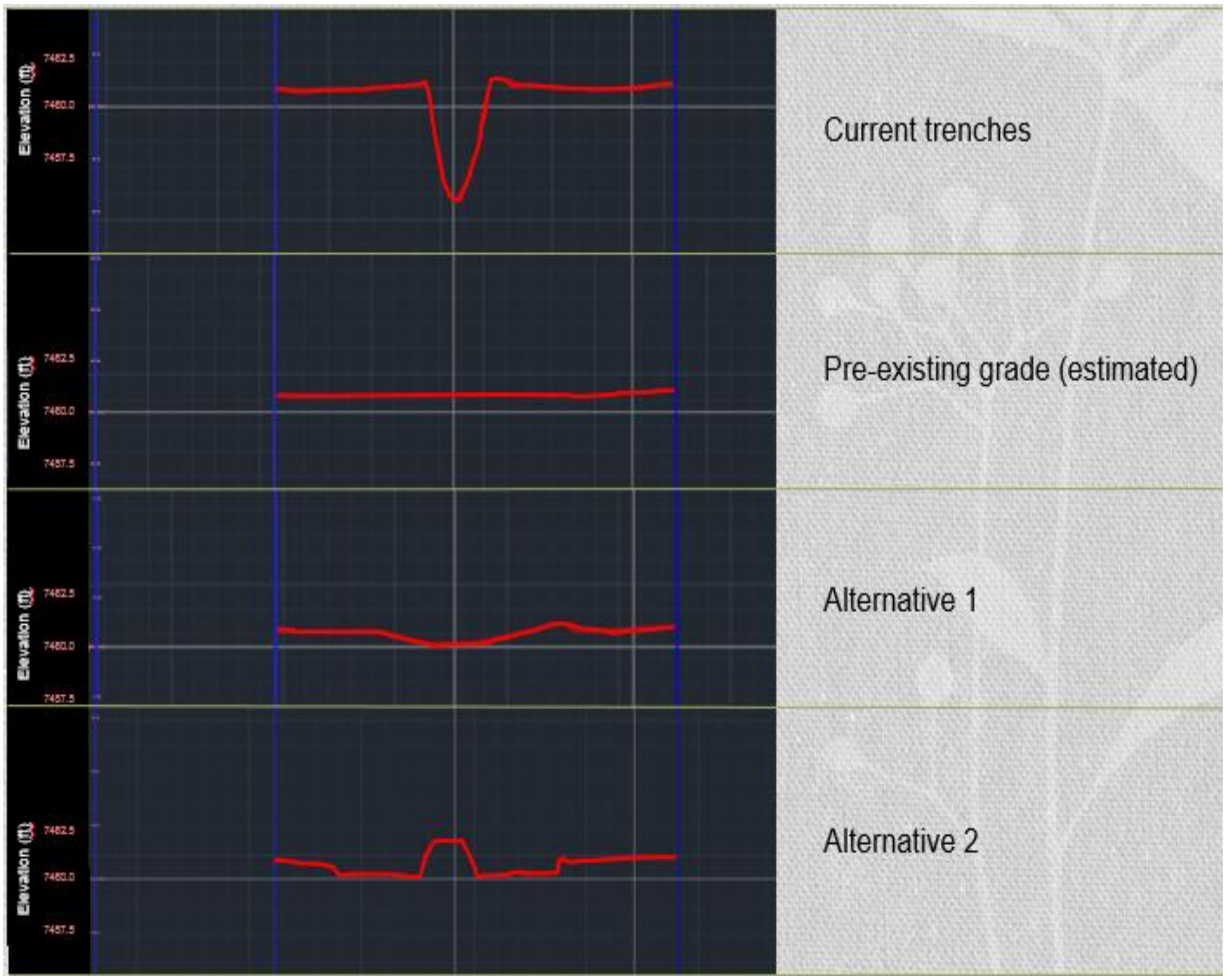


Figure 3.21: Comparison of design cross sections.

Regardless of the construction method based on the alternatives, the top six inches of soil will have to be removed due to high amounts of organic content (plant matter) as well as the trenches being filled with side casted material. In the figures, it shows a simplistic view of what the trenches would look like with yellow being side casted material, green is the clay layer, and red being the sandy lean clay:

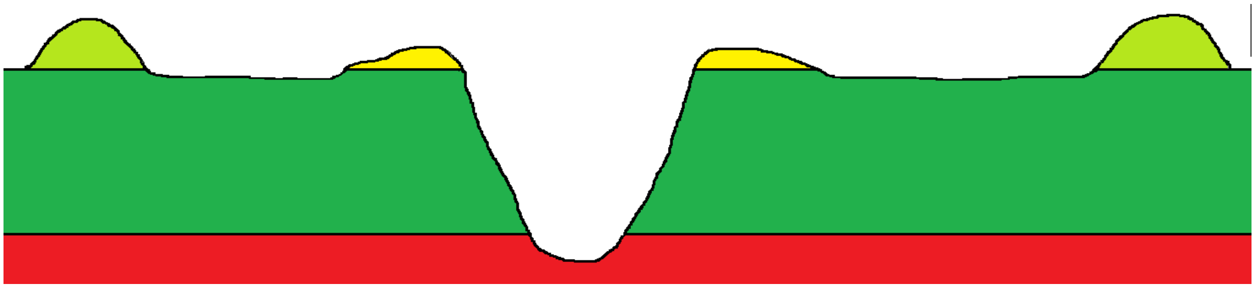


Figure 3.22: Existing conditions near trenches at Allan Lake with six inches removed.

In addition, in this figure below, it shows the side casted material put into the trenches as well as the 6 inches of top side removed:

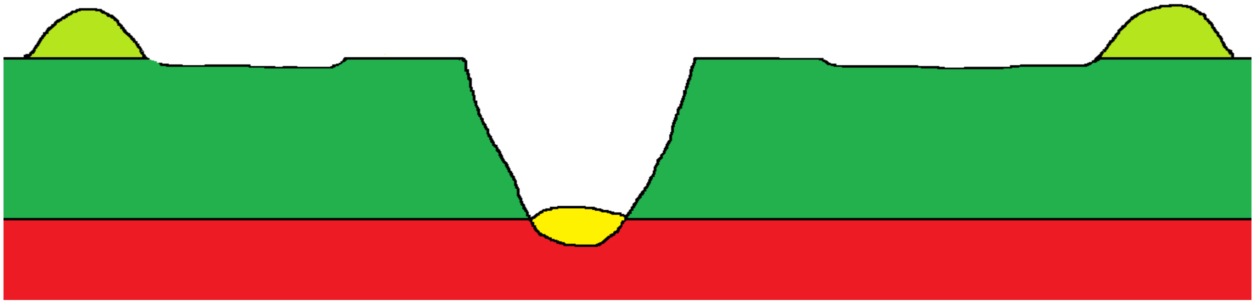


Figure 3.23: Side cast material backfilled into trench.

For alternative 1, the plan is to raise the trenches to 1 foot below the pre-existing grade (as shown in figure 3.21). The benefits of this alternative are to lower the cost, lower the evaporation rate, and efficient construction time. The figure below shows alternative 1:

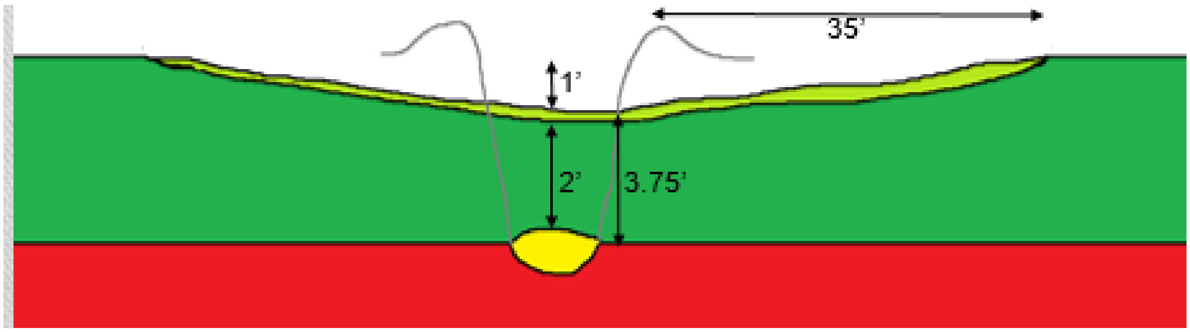


Figure 3.24: Design alternative 1.

For alternative 2, the plan is to raise the trenches to 0.75 feet above the preexisting grade line. This way, the infiltration rate is lower, provides more protection from large animals, and they are less prone to freeze and thaw cycles. In the figure below, it shows design alternative 2:

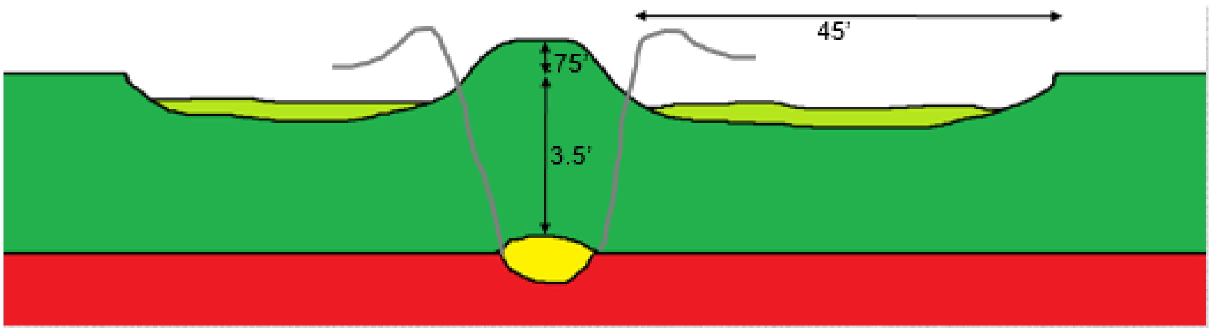


Figure 3.25: Design alternative 2.

For design alternative 1, the total amount of earthwork is 21,000yd^3 of clay cut and 21,000 yd^3 of clay fill with 12,800 yd^3 of topsoil cut and 12,800 yd^3 topsoil fill. For the following figure and table, they show the proposed cut and fill for alternative 1 with a key as part of the table:

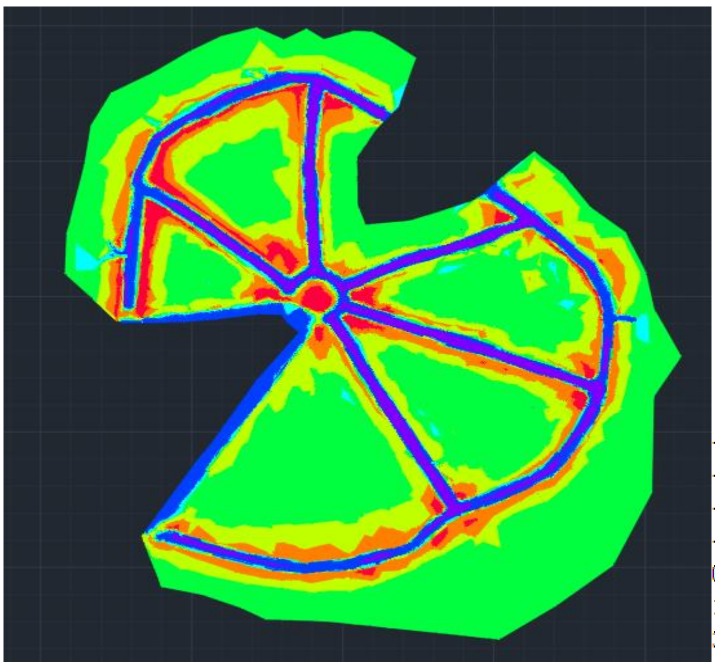


Table 3.27: Key for alternative 1.

Minimum Elevation	Maximum Elevation	Color Scheme
-10.00'	-1.75'	
-1.75'	-1.00'	
-1.00'	-0.25'	
-0.25'	0.25'	
0.25'	1.00'	
1.00'	3.00'	
3.00'	10.00'	

Figure 3.26: Alternative 1 cut and fill.

This proposed alternative 1 cut and fill was determined by using a shrink factor of 1.33 and a swell factor of 1.40.

For design alternative 2, the total amount of earthwork is 29,960 yd^3 of clay cut and 29,960 yd^3 of clay fill with 18,000 yd^3 of topsoil cut and 18,000 yd^3 topsoil fill. For the following figure and table, they show the proposed cut and fill for alternative 2 with a key as part of the table:

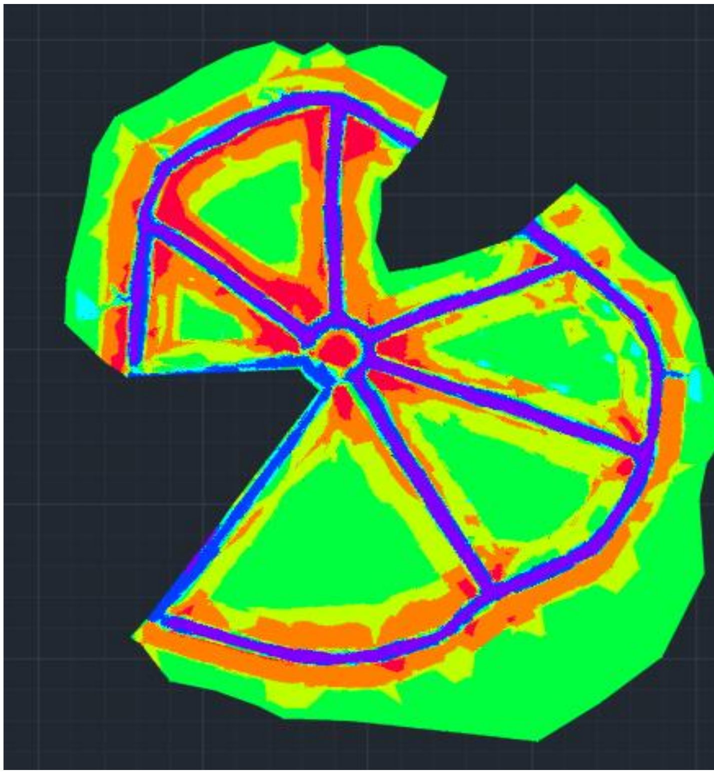


Table 3.29: Key for alternative 2.

Minimum Elevation	Maximum Elevation	Color Scheme
-10.00'	-1.75'	
-1.75'	-1.00'	
-1.00'	-0.25'	
-0.25'	0.25'	
0.25'	1.00'	
1.00'	3.00'	
3.00'	10.00'	

Figure 3.28: Proposed cut and fill for alternative 2.

This proposed alternative 2 cut and fill was determined by using a shrink factor of 1.33 and a swell factor of 1.40.

3.30 Cost of Implementation

For the cost analysis for each alternative, the team had contacted a contractor, Pete Page. Pete was able to provide the team will unit costs that incorporate the amount of soil that would need to be moved during cut and fills and top soil removal and redistribution. The unit cost also takes into consideration the transportation and machines used during construction. The unit cost was $8.50 per cubic foot for the cut and fill of on-site clay and $11.50 per cubic foot for the top soil removal and redistribution. As shown below is the table for the cost analysis of alternative 1:

Table 3.31: Alternative 1 cost analysis.

Alternative 1	Quantity (ft^3)	Unit Cost ($)	Item Cost ($)
Cut & Fill of On-Site Clay:	21,000	$8.5 per cubic ft.	$178,500
Top Soil Removal and Redistribution:	12,800	$11.5 per cubic ft.	$147,200
Total Cost			**$325,700**

The next table is Alternative 2 cost analysis shown below:

Table 3.32: Alternative 2 cost analysis.

Alternative 2	Quantity (ft^3)	Unit Cost ($/ft^3)	Item Cost ($)
Cut & Fill of On-Site Clay:	29,960	$8.5 per cubic ft.	$254,660
Top Soil Removal and Redistribution:	18,000	$11.5 per cubic ft.	$207,000
Total Cost			**$461,660**

The total cost for alternative 1 was $325,700 which was $135,960 less than alternative 2. However alternative 2 provides more benefits as mentioned in section 3.20.

4.0 Summary of Project Costs

For our project, the tasks were completed on time except for a few of the geotechnical lab analysis. As mentioned before in section 2.3, weather conditions posed a life risk on every team member. But also, the fact that ice covering the soil prevented any excavation possible and due to the weather conditions, we had to postpone the lab analysis until later in the semester when it was possible to collect more samples.

Shown below is our original Gantt Chart

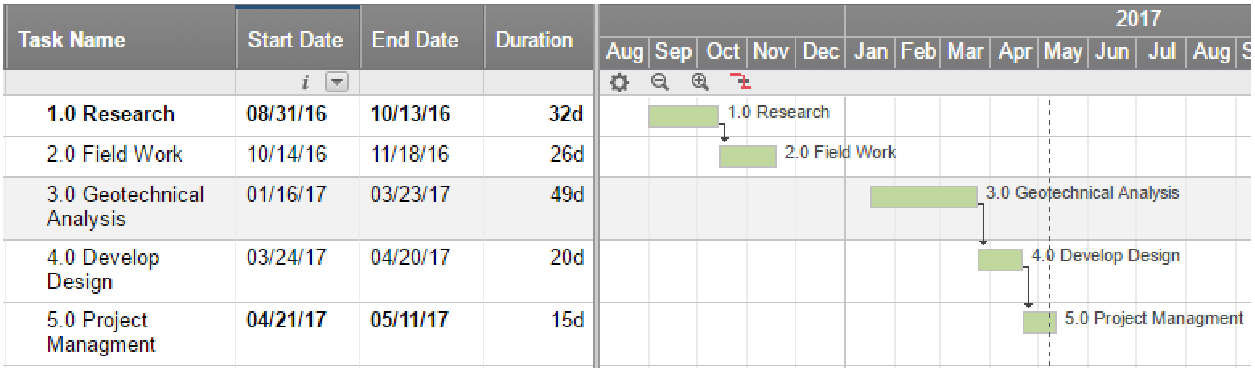


Figure 4.1**:** Gantt Chart original.

In our final Gantt Chart (in the figure on the next page), you can see that the time was extended to April 5th for our geotechnical lab analysis due to the limitations as stated before:

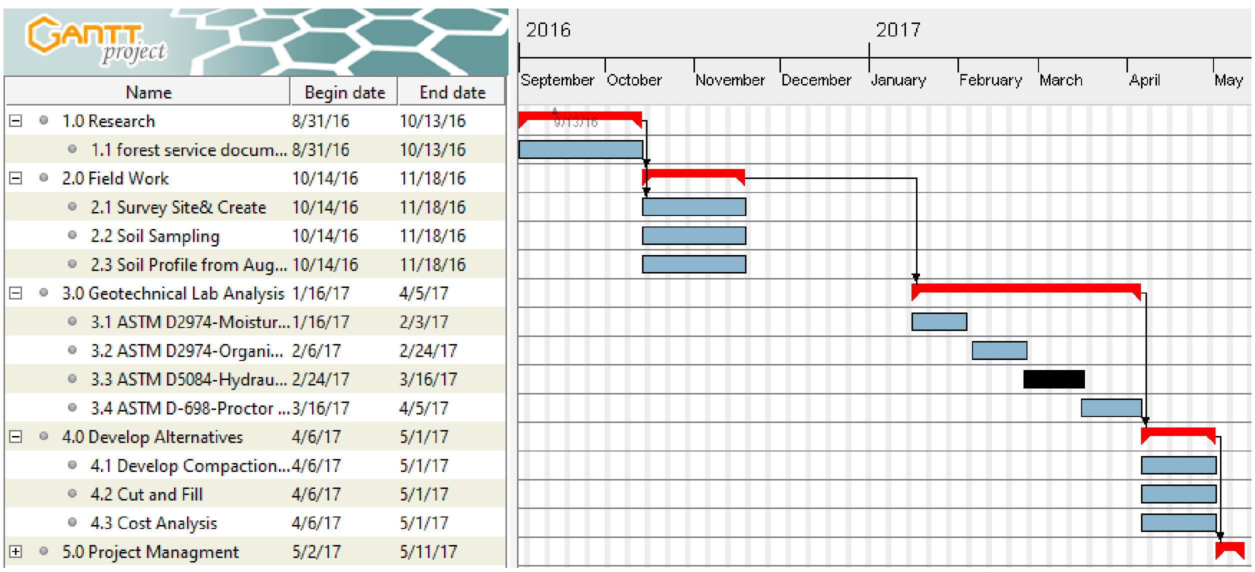


Figure 4.2: Gantt Chart revised.

In addition, the postpone work on the geotechnical lab work also affected the amount of hours estimated for the geotechnical lab technician. As shown below, is the table that states how many hours each personnel worked:

Table 4.3: Staffing cost for Allan Lake project.

1.0 Personnel	Staff	Projected Hours	Actual Hours	Rate, $/hr	Projected Cost	Actual Cost
	Project Engineer	40	45	163	$ 6,520.00	$ 7,335.00
	Engineer	45	65	88	$ 3,960.00	$ 5,720.00
	Geotechnical Technician	220	160	45	$ 9,900.00	$ 7,200.00
	Surveyor	120	100	65	$ 7,800.00	$ 6,500.00
	Administrative Assistant	35	45	45	$ 1,575.00	$ 2,025.00
	Intern	25	35	30	$ 750.00	$ 1,050.00
Total Personnel =		485	450	436	$30,505.00	$29,830.00
2.0 Travel	5 Meetings @ 55 mi/meeting	$2.00/mi			$ 100.00	$ 100.00
3.0 Total					$30,605.00	$29,930.00

Highlighted in red is the amount of work that we went under (due to weather conditions at the project site). However, highlighted in blue indicates the hours that we went over due to a misunderstanding on the amount of hours needed to complete each project deliverable, client meetings, technical advisor meetings, and the amount of hours for developing the AutoCAD files. Furthermore, we were able to meet the 450 hours for this project which was 35 hours under our projected hours. Similarly, the projected cost was $30,605 which was a little bit over the actual cost which was $29,930.

5.0 References

[1] T. Runyon. (2016, September 6). *Allan Lake Statement of Work* [Online]. Available email: tarunyon@fs.fed.us Message: Introduction.

[2] US Forest Service United States of Department of Agriculture (2016). *Allan Lake Wet Rest Decision Memo Final*. [Online]. Available Telnet: http://www.fs.usda.gov/ Directory: Allan Lake Wetland Restoration Project: Decisions

[3] US Forest Service United States of Department of Agriculture (2016). *Decision Cover Letter*. [Online]. Available Telnet: http://www.fs.usda.gov/ Directory: Allan Lake Wetland Restoration Project: Decisions

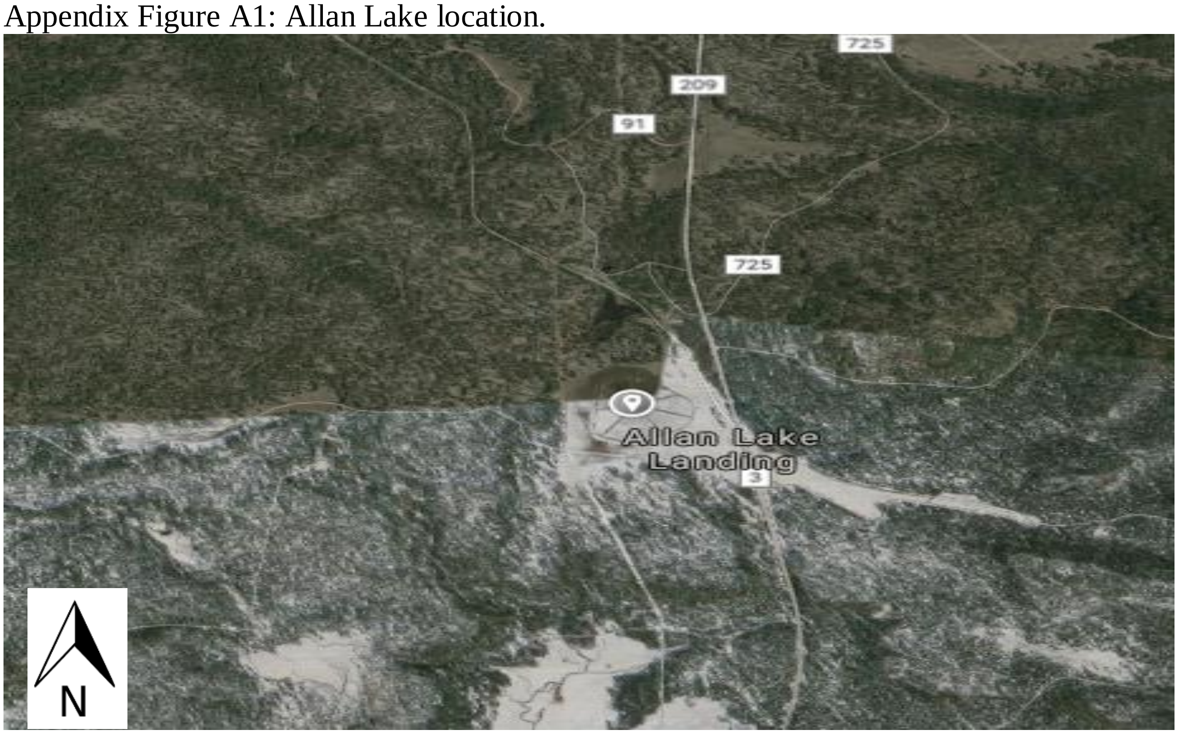
[4] Google Earth. (2016). *Allan Lake Google Earth* [Online] Available: FTP: https://www.google.com/earth/

[5] B. Gutierrez, G., Green, S., Clemons. (2016, December 2016). *Student Project Proposal.* Print.

6.0 APPENDICES

APPENDIX A- Location of Allan Lake on Google Earth [4]

Appendix Figure A1: Allan Lake location.



Appendix Figure A2: Allan Lake location.

APPENDIX B- Arial View of the Trenches of Allan Lake

Appendix Figure B1: View of trenches of Allan Lake.

APPENDIX C- Current landscape of the project

Appendix Figure C1: Differences in vegetation between the test restoration section on the right and the unrestored section on the left. (September 13th, 2016)

Appendix Figure C2: Small puddle of water in the deepest portion of the restored section. (September 13th, 2016)

Appendix Figure C3: Unrestored trench in the southeast portion of the site. (September 13th, 2016)

Appendix Figure C4: Overview of flooded wetland (February 17th, 2017)

Appendix Figure C5: Looking at the test restoration section on the left and the unrestored section on the right, with the lake at full capacity. (February 17th, 2017)

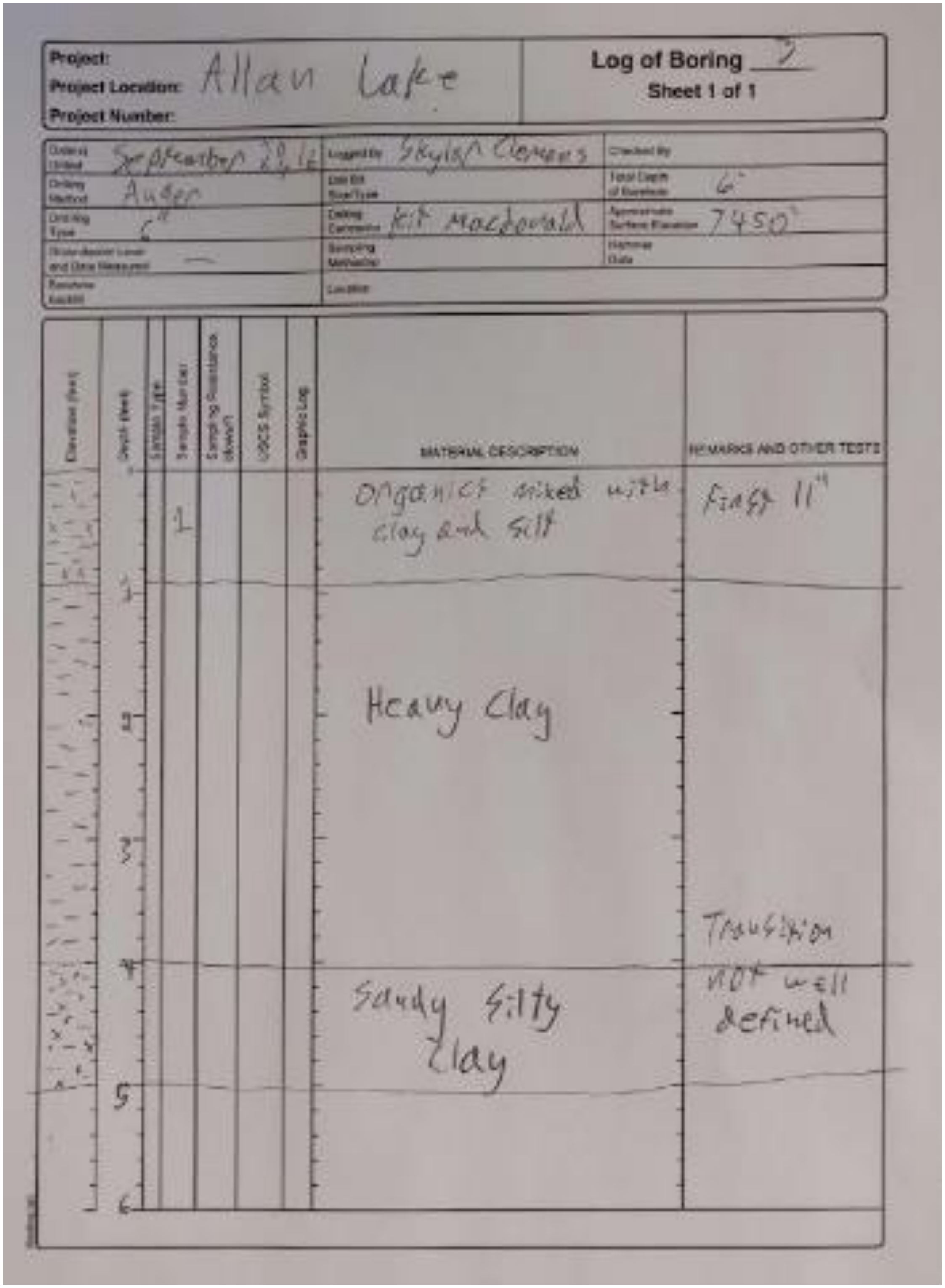
Appendix Figure C6: Trenches in the unrestored area covered by ice during the winter. (February 17th, 2017)

APPENDIX D: Lab Results

		Before oven	After oven	After furnace		
Samples	**Wc**	**W1**	**W2**	**W3**	**Moisture (%)**	**Organic Content (%)**
1	21.83	52.14	47.52	45.58	17.98365123	8.168421
2	13.72	35.26	30.09	28.71	31.58216249	9.206137
3	14.15	44.3	41.95	40.15	8.45323741	6.923077
4	13.5	47.94	45.86	44.63	6.427688504	3.951173
5	13.82	34.13	31.89	30.38	12.39623686	9.118357
6	14.22	47.31	42.7	40.41	16.18679775	8.743795
7	21.83	40.97	38.84	37.55	12.52204586	8.206107
8	14.2	27.6	26.04	25.12	13.17567568	8.424908
9	13.97	40.48	35.51	33.89	23.0733519	8.13253
10	22.6	71.11	67.39	64.5	8.305425318	6.897375
11	22.27	90.47	84.3	79.89	9.946799936	7.653593
12	13.74	53.37	41.76	39.72	41.43468951	7.852194
13	14.4	31.97	29.41	28.1	17.05529647	9.562044
14	13.58	34.08	29.02	27.54	32.77202073	10.60172
15	14.05	35.28	31.91	29.99	18.86898096	12.04517
16	11.98	29.76	28.22	27.21	9.482758621	6.631648
17	14.57	29.55	28.23	27.23	9.663250366	7.898894
18	14.33	26.79	25.68	24.86	9.779735683	7.787274
19	13.23	36.17	32.52	31.1	18.9217211	7.946279
20	14.08	24.93	23.13	22.4	19.88950276	8.774038
21	22.27	39.19	37.61	36	10.29986962	11.72615
22	11.76	49.11	45.54	43.23	10.56838366	7.340324
23	13.84	45.18	41.69	39.81	12.53141831	7.239122
24	13.64	36.22	33.17	31.5	15.61699949	9.350504
25	11.36	32.31	29.61	28.04	14.79452055	9.41247
26	22.18	27.49	27.04	26.69	9.259259259	7.760532
27	22.7	38.07	35.83	34.74	17.06016756	9.053156
28	12.34	38.7	35.35	33.46	14.55888744	8.948864

Appendix Table D1: Results of the organic test.

Appendix E: Bore logs


Project:
Project Location: Allan Lake
Project Number:

Log of Boring 3
Sheet 1 of 1

Date(s) Drilled	September 28, 16	Logged By	Skyler Clemens	Checked By	
Drilling Method	Auger	Drill Bit Size/Type		Total Depth of Borehole	6'
Drill Rig Type	6"	Drilling Contractor	Kit Macdonald	Approximate Surface Elevation	7450'
Groundwater Level and Date Measured	—	Sampling Method(s)		Hammer Data	
Borehole Backfill		Location			

Elevation (feet)	Depth (feet)	Sample Type	Sample Number	Sampling Resistance (blows/ft)	USCS Symbol	Graphic Log	MATERIAL DESCRIPTION	REMARKS AND OTHER TESTS
	0–1		1				organics mixed with clay and silt	Grass 11"
	1–4						Heavy Clay	Transition
	4–5						Sandy Silty Clay	not well defined
	5–6							

Appendix Figure E1: Bore log from sample site 3 in the undisturbed area